Together we move

Future Traction Systems - from Vision to Reality

Creating Sustainable Value at Sustainable Cost

KTH Railway Group Seminar
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Rolling Stock Equipment Division, Energy and Motion
Bombardier Transportation Sweden
May 22, 2019

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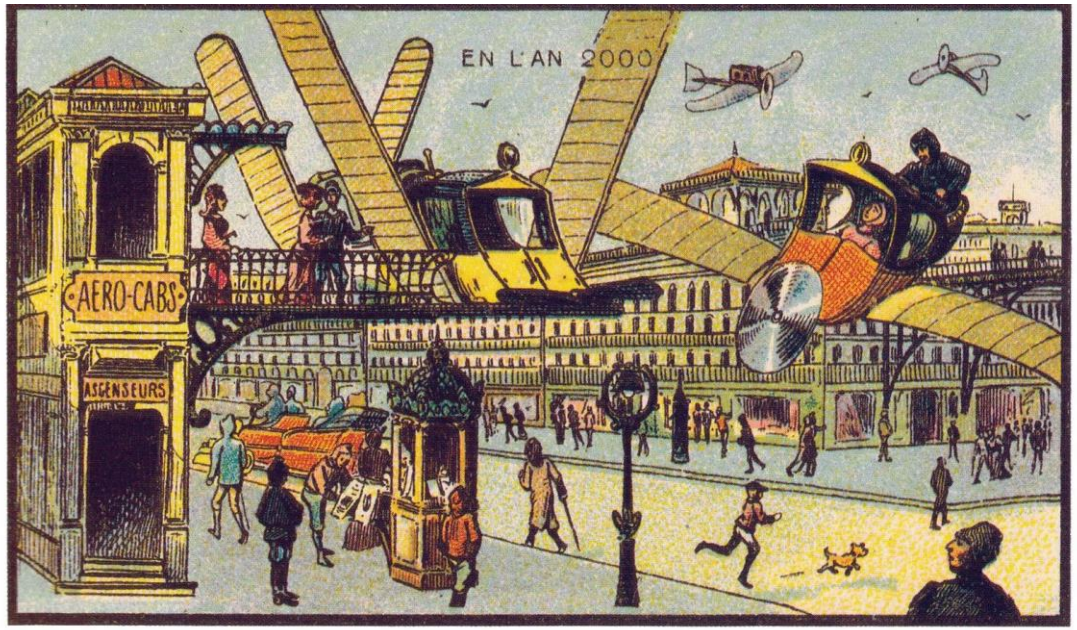
”Of how the future will unfold, the past floats in blissful ignorance”

- Christina, Queen of Sweden (1632 – 1654), written ca 1682

“Rail travel at high speed is not possible, because passengers, unable to breathe, would die of asphyxia.”

- Dr. Dionysius Lardner, professor of Natural Philosophy and Astronomy, 1823



Aero-Cab Station

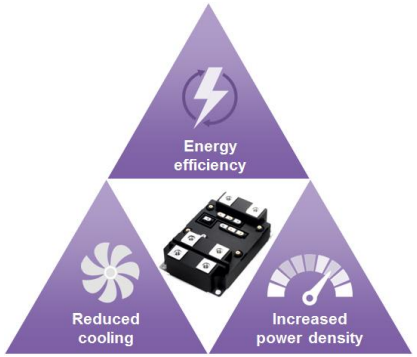
Post card image depicting the world in 2000 created by J Villemard for the 1900 Paris World Exhibition

- Source Wikimedia Commons

Recent Railway Propulsion breakthroughs at BOMBARDIER

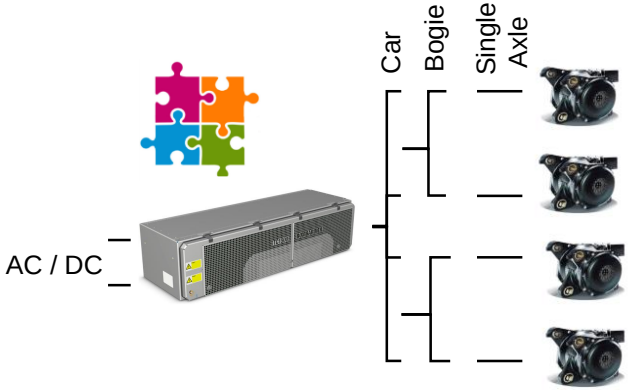
MITRAC 3 LAUNCHED – Propulsion solutions for the next decade

Future Performance Captured



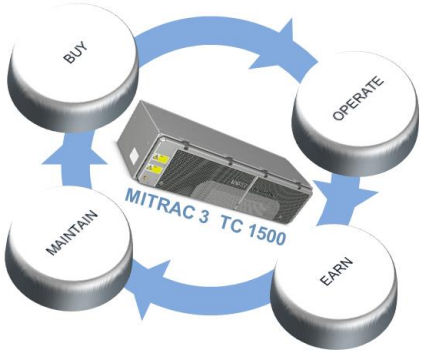
SiC Ready

Modular Flexibility



ASM / PMSM

Customer Value Achieved



R&D – in partnership

SiC Converter in Stockholm MOVIA Metro 2018

- **- 34%** propulsion losses
- **- 22%** size
- **- 51%** weight
- **- 19 dB** noise

GreenSiCtrac Demo

Energimyndigheten · SL · MTR · KTH · RI. SE

Battery power in TALENT EMU 2018

100 km range, 7-8 min recharge

Talent 3 BEMU

Bundesministerium für Verkehr und digitale Infrastruktur · DB · NVBW Nahverkehrsgesellschaft Baden-Württemberg mbH · berlin · NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Is there a need for new Propulsion Technologies?

MEGATREND perspectives

Extrapolated Mega Trends

- Population Growth
- Urbanization
- Digitization & Connectivity
- Climate Change

Railway Impact

- Higher Capacity
- Higher Availability
- Improved Intermodality

Propulsion Design Parameters

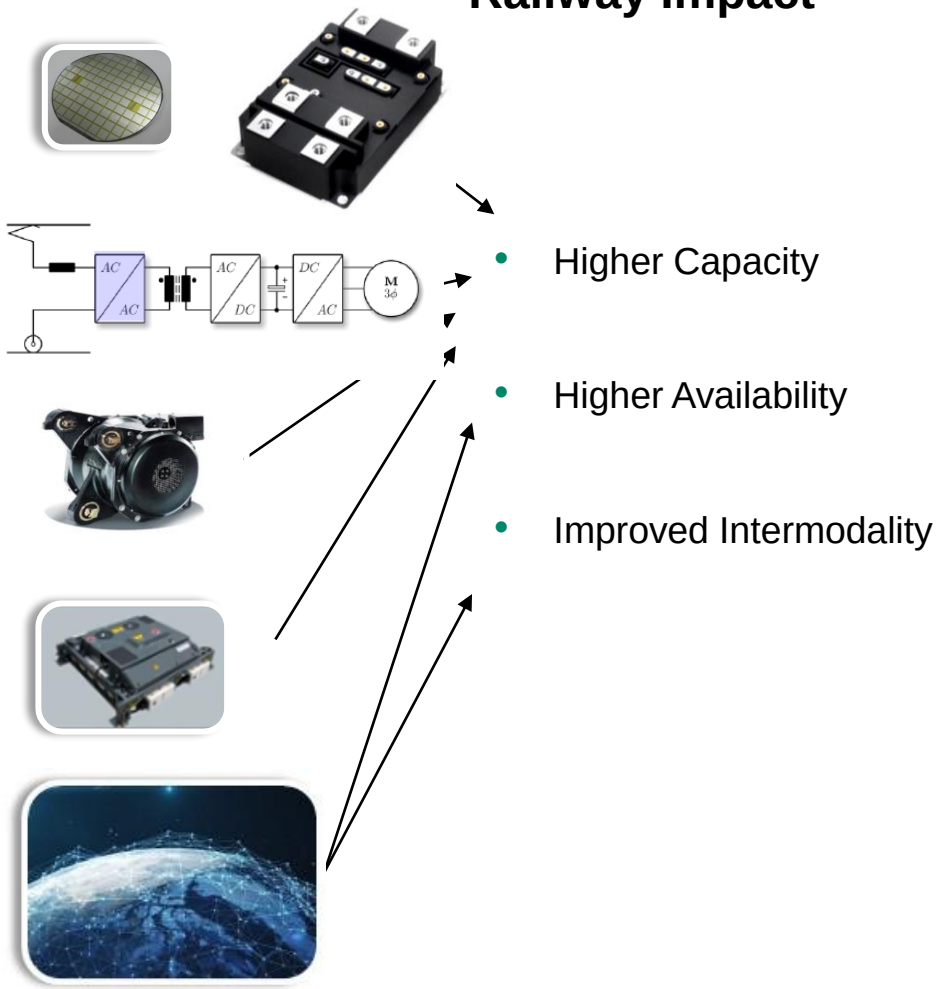
- Performance
- Integration
- Availability
- Infrastructure
- Maintenance

Propulsion Technology Evolution

Possibilities and Impact

	Categories	Possible Alternatives and Evolution paths	
Semiconductors	**Devices**	Si	SiC MOSFETS - Planar, Trench SiC Bipolar, IGBT
	Package	Industrial	Traction
Converter Design	**Topology**	Multilevel	Medium Frequency
	Cooling	Forced (Air/Water)	Car Motion
Motors	**Magnetization**	Induction	PM Synchronous, Assisted Synchronous Reluctance
	Electrical	3-phase	6-phase
	Mechanical/Thermal	Lightweight	
Energy storage	**Battery**	Li-Ion	Flow
	Fuel cell	Hydrogen	
Digitization	**Communication**	Dedicated networks	5G
	Data management	Assisted Learning	Machine Learning / AI
	Virtualization	Model Based Design and Test	

Railway Impact

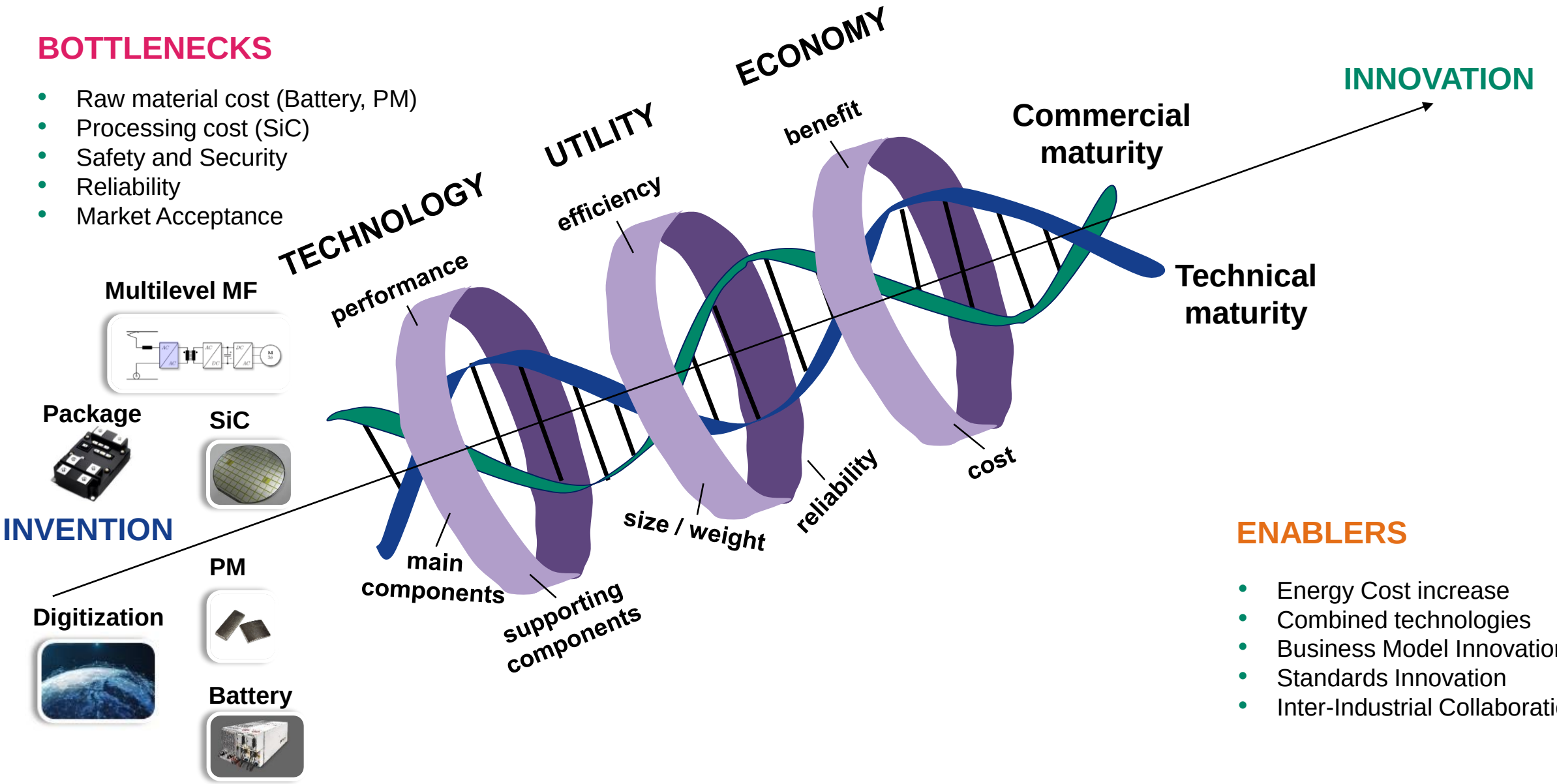


- Higher Capacity
- Higher Availability
- Improved Intermodality

Trade-offs in Powertrain Innovation

BOTTLENECKS

- Raw material cost (Battery, PM)
- Processing cost (SiC)
- Safety and Security
- Reliability
- Market Acceptance



ENABLERS

- Energy Cost increase
- Combined technologies
- Business Model Innovation
- Standards Innovation
- Inter-Industrial Collaboration

Ganesh Chandramouli | RoQ | 2019-05-22 | Rev. 0 |

What would drive the choice of Technologies?

Dealing with Uncertainty – Evaluating Outcomes?

Extrapolated Mega Trends

- Population Growth
- Urbanization
- Digitization & Connectivity
- Climate Change

- Higher Capacity
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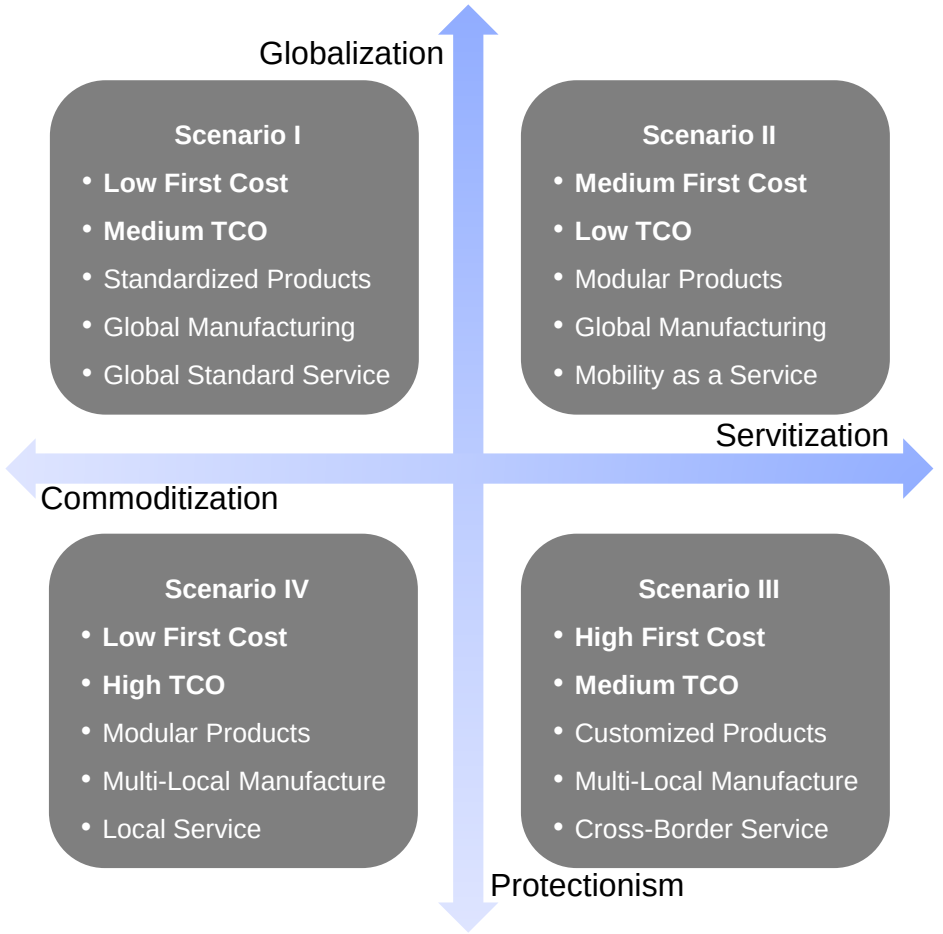
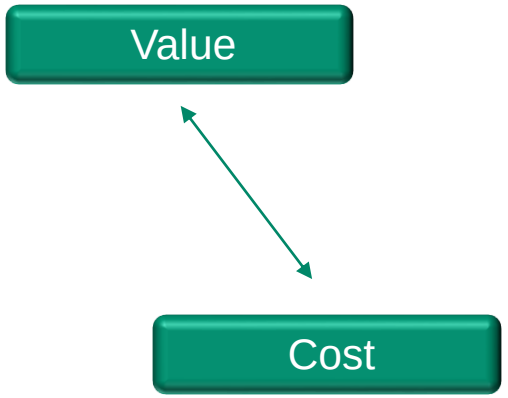
- Improved Intermodality

Uncertain Trend Scenarios



Evaluation – Axis of Sustainability

(reduced environmental footprint)



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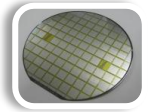
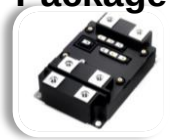
Technology Applications?

Scenario examples – choices still abound

Device



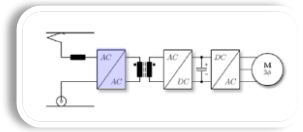
Package



Motor

Battery

Topology



Digitization

SiC IGBT

SiC MOSFET

Industrial

Assisted Reluctance

PM energy efficient

PM few driven axles

Multilevel MF AC

Digitized Manufacture

Virtual Homologation

Digitized Service and Manufacture

Scenarios

Globalization

Protectionism

Commoditization

Servitization

Scenario I
- Low First Cost
- Medium TCO
- Standardized Products
- Global Manufacturing
- Global Standard Service

Scenario II
- Medium First Cost
- Low TCO
- Modular Products
- Global Manufacturing
- Mobility as a Service

Scenario III
- High First Cost
- Medium TCO
- Customized Products
- Multi-Local Manufacture
- Cross-Border Service

Scenario IV
- Low First Cost
- High TCO
- Modular Products
- Multi-Local Manufacture
- Local Service

Evaluation – Axis of Sustainability

(reduced environmental footprint)

Value

Cost

Choosing Sustainable Value at Sustainable Cost

What do we want to achieve together and how soon?

Areas of Influence

Business Models

Buying models considering Energy Cost and Emissions?

Data sharing, ownership and security models?

Standards

Service Life << 30 years?

Noise emission levels?

Virtual Homologation?

Combined Techologies

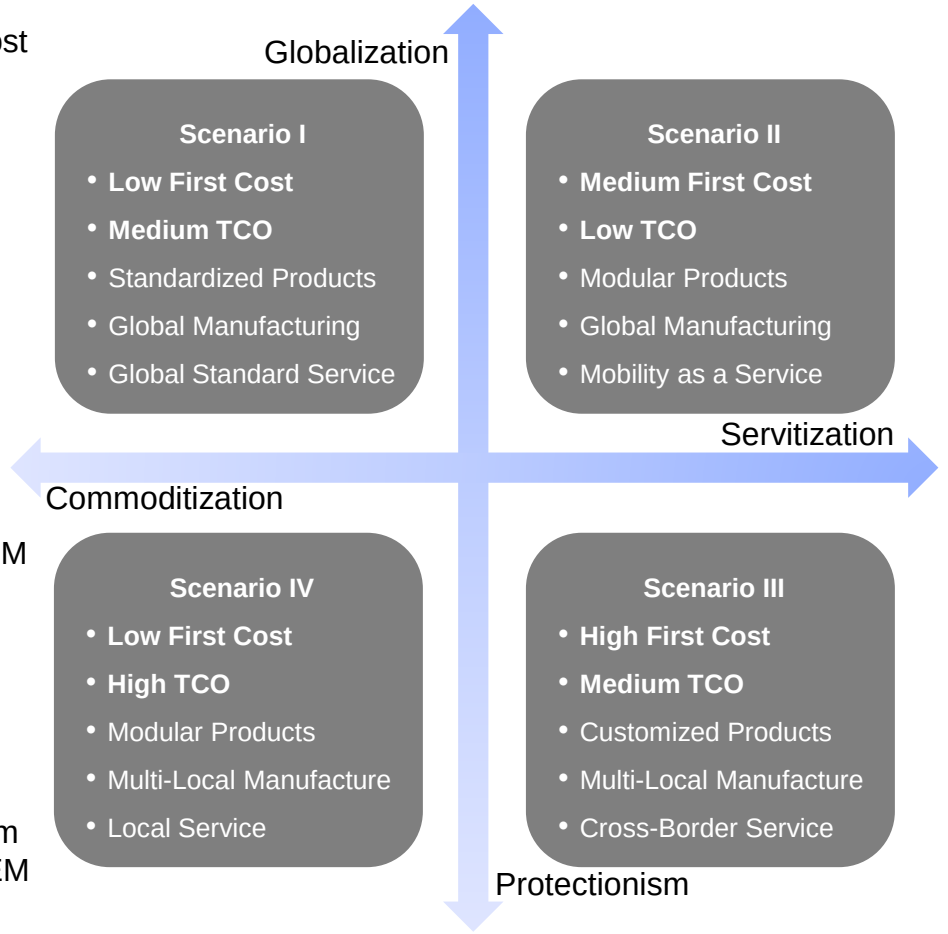
SiC + Digitized optimization ➔ Less PM /Battery Cost ➔ High SiC volumes ➔ Less SiC Cost

Inter-Industrial Collaboration

Road e-mobility + Rail + Telecom

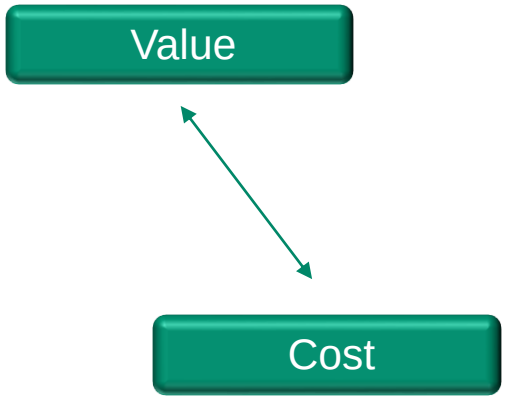
Intermmodality & Railway supersystem Rolling Stock Owner + Operator + OEM + Infrastructure Owner

Scenarios



Influence Outcomes – Axis of Sustainability

(reduced environmental footprint)



If our end goal is sustainability at an attractive cost we can influence this outcome in most scenarios by innovative Business Models, Standards and Collaboration. Technology innovation will follow.

"The future's not set. There's no fate but what we make for ourselves."

- character John Connor in motion picture Terminator 2 Judgement Day, James Cameron 1991

Questions & answers

Thank you very much!

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